14th ICCRTS

"C2 and Agility"

Challenges for digitisation – learning from analogue mission planning teams

Topic 1: C2 Concepts, Theory, and Policy
Topic 3: Information Sharing and Collaboration Processes and Behaviors
Topic 8: C2 Assessment Tools and Metrics

Professor Neville A. Stanton, Dr Guy H. Walker, Dr Paul M. Salmon, Dr Daniel P. Jenkins & Laura A. Rafferty

Contact: Professor Neville Stanton
N.Stanton@soton.ac.uk
Defence Technology Centre for Human Factors Integration (DTC HFI)
School of Civil Engineering and the Environment
University of Southampton
Highfield
Southampton
[UK] SO17 1BJ

Tel: 02380 595000
n.stanton@soton.ac.uk

Paper ID# 065

Challenges for digitisation – learning from analogue mission planning teams

Abstract
This paper aims to consider the conventional, analogue, mission planning process with the objective of identifying the decision making constraints and challenges for digitisation. Prototypes of digital mission planning systems are beginning to be devised and demonstrated, but there has been concern expressed over the design of such systems which fail to understand and incorporate the human aspects of socio-technical systems design. Previous research has identified many of the potential pitfalls of failing to take Human Factors considerations into account as well as the multiplicity of constraints acting on the planners and planning process. An analysis of mission planning in a Battle Group is presented, based on an observational study by the authors. This study illustrates the efficiency of an analogue process which has evolved over many generations to form the Combat Estimate, a process that is mirrored by forces throughout the world. The challenges for digitisation include ensuring that the mission planning process remains easy and involving, preserving the public nature of the products, encouraging the collaboration and cooperation of the planners, and maintaining the flexibility, adaptability and speed of the analogue planning process. It is argued that digitisation should not become an additional constraint on mission planning.

Introduction to mission planning
Mission failure is often thought to be the result of poor mission planning (Levchuk et al., 2002), which places considerable demands on the planners and the planning process. This observation is further confounded by the two general principles of warfare. The first principle is that of the *"fog of war"* (i.e., the many uncertainties about the true nature of the environment - Clausewitz, 1832) and second the principle that *"no battle plan survives contact with the enemy"* (i.e., no matter how thorough the planning is, the enemy is unlikely to be compliant and may act in unpredictable ways - von Moltke, undated). These three factors (i.e., the effects of uncertainty, the enemy and failure on mission planning) require the planning process to be robust, auditable and flexible. Mission planning has to be a continuous, iterative and adaptable process, optimising mission goals, resources and constraints (Levchuck, 2002). Roth, et al. (2006) argue that the defining characteristic of command and control is the continual adaptation to a changing environment. Constant change in the goals, priorities, scale of operations, information sources and systems being used means that the planning systems need to be extremely adaptable to cope with these changes. According to Klein and Miller (1999) there are many constraints acting on mission planning, including scarcity of resources, time pressure, uncertainty of information, availability of expertise, and the structure of the tasks to be undertaken. Mission planning requires knowledge of the domain, objects in the domain and their relationships as well as the constraints acting on the domain, the objects and their relations (Kieweit, et al., 2005). They also note that the planning cycles can range from a couple of hours to a few days depending upon the complexity of the situation and the time available. Given all of the constraints acting on the planning process and

the need for the plan to be continually revised and modified in the light of the enemy actions and changing situation, Klein and Miller (1999) argue that *"simpler plans might allow better implementation and easier modification"* (p. 219). This point is reinforced by Riley, et al. (2006) who assert that *"Plans need to be simple, modifiable, flexible, and developed so that they are quickly and easily understood"* (Ibid, p. 1143).

Mission planning is an essential and integral part of battle management. Although there are some differences within and between the armed services (and the coalition forces) in the way they go about mission planning, there are also some generally accepted aspects that all plans need to assess. These invariants include: enemy strength, activity and assumed intentions, the goals of the mission, analysis of the constraints in the environment, the intent of the commander, developing courses of action, choosing a course of action, identifying resources requirements, synchronising the assets and actions, and identifying control measures. A summary of the planning process for the United States Army may be found in Riley et al. (2006) and the Canadian Army may be found in Prefontaine (2002). Their description has much in common with land-based planning in the British Army, which is described in The Combat Estimate booklet (CAST, 2007).

Observation of Mission Planning in a Battle Group

The mission planning process has been observed by the authors at the Land Warfare Centre at Warminster in the United Kingdon and on training exercises in Germany. The observations at Warminster have been both as participant-observers and as normal observers. This section describes the observed activities in the planning process following a Warning Order received from Brigade. For the purpose of this analysis, only the conventional materials (whiteboards, maps, overlays, paper, flipcharts and staff officers' notebooks) will be examined. As Figure 1 shows, the planning is undertaken in a 'public' environment when various people contribute and all can view the products. This 'public' nature of the products is particularly useful at the briefings, which encourages collaboration and cooperation. It also helps to focus the planners' minds on the important issues and the command intent.

Figure 1 - Battle Group Head Quarters – Public Planning Area (G5)

The following vignette describes how a Battle Group Head Quarters was observed to conduct itself in the planning process. Whilst other Battle Group Head Quarters might vary, the basic themes are likely to be similar in processes they follow and products they produce.

Warning Order from Brigade arrived
The Warning Order (WO) arrived and was handed to the Chief of Staff (CoS) who read the whole document first, highlighting relevant material for himself and the Company level.

Chief of Staff (CoS) creates Company WO
The WO was too detailed for Company level, so some editing by CoS was necessary, as well as the inclusion of some additional material to clarify the anticipated task requirements.

Send WO to Companies
The modified and edited WO was then sent to the companies below the Battle Group, so that they would have advanced notice of the intention of the orders when they arrived. This gives them an opportunity to prepare in advance of the actual orders.

Create planning timeline
The CoS created a planning timeline for the production of a plan to defeat an assault team that had parachuted into their area. There were two hours available to construct the plan (from 1300 to 1500), which allotted approximately 17 minutes per question (of the Combat Estimate's 7 questions) as shown in Appendix 1. The planning timeline was drawn on a flipchart. The Combat Estimate is a planning process that

has been developed over decades and is described in more detail in The Combat Estimate book issued by the Command and Staff Trainer organisation at the Land Warfare Centre in Warminster, UK (CAST, 2007). The Combat Estimate has 7 main questions to guide planners through the process, namely:

Q1. What is the enemy doing and why?
Q2. What have been I told to do and why?
Q3. What effects do I want to have on the enemy and what direction must I give to develop my plan?
Q4. Where can I best accomplish each action/effect?
Q5. What resources do I need to accomplish each action/effect?
Q6. Where and when do each of the actions take place in relation to each other?
Q7. What control measures do I need to impose?

The activities that were observed in answering each of these questions are presented.

Q1. What is the enemy doing and why?

Question 1 was undertaken by the Engineer and the Intelligence Officer in parallel with Question 2. Key terrain features were marked on a transparent overlay placed on top of a map (such as slow-go areas like forests and rivers), as were the approximate disposition of the enemy forces and likely locations (using translucent stickers with the standard military symbols on them from APP-6A - NATO standardization agreement on Military Symbols for Land Based Systems), potential avenues of approach, and likely Courses of Action (CoA). An example is shown in Appendix 2. In this case, it was thought that the enemy assault force was likely to try and meet up with the main armoured forces approaching from the West. The enemy had landed in an area surrounded by forest which gave them some protection, although it was thought that they had not landed where they intended.

Q2. What have I been told to do and why?

The CoS interpreted the orders from Brigade together with the Battle Group commander to complete the Mission Analysis. Each line of the orders was read and the specified and implied tasks were deduced. These were written by hand onto a whiteboard as shown in Appendix 3. The Commander's Critical Information Requirements (CCIRs – which are linked to the Decision Points in Questions 4 and 5) and Information Requests (IRs) were identified and noted for each task, when appropriate. When the CCIRs/IRs had been derived, the CoS read them off the Mission Analysis whiteboard (expanding where necessary to improve intelligibility) to a clerk who typed them directly onto the Requests For Information (RFI) sheet. The requests were radioed up to Brigade and the responses were tracked on the whiteboard.

Q3. What effects do I want to have on the enemy?

The Battle Group Commander then drew his required effects onto a flipchart as shown in Appendix 4. Three effects were placed above the planning line (SCREEN, CLEAR and DEFEAT) and four effects were placed below the planning line (SCREEN, DEFEAT, GUARD and DEFEND). The two SCREEN effects were placed to prevent the enemy from the West coming to the aid of the group who were being attacked. The CLEAR effect was intended to remove any enemy from the forest, if they were there. The DEFEAT effect was intended to incapacitate the enemy.

Q4. Where can I best accomplish each action/effect?
The CoS and Battle Group Commander worked on three COAs to achieve the Commander's effects as shown in Appendix 5. This was a very quick way to propose and compare three potential COAs in response to the Battle Group Commander Effects Schematic (remembering that the planning timeline only allowed 17 minutes for each of the seven questions of the Combat Estimate). Meanwhile the Engineer took the Battle Group Commander's Effects Schematic and put the Effects onto the ground, using an acetate sheet on a paper map. Each Effect became either a Named Area of Interest (NAI) or a Target Area of Interest (TAI). Decision Points (DP) were placed between NAIs and TAIs. The resultant overlay is called the Decision Support Overlay (DSO) as shown in Appendix 6. It is worth noting that it took approximately 15 minutes to construct the DSO on the TALC (by the Engineer).

Q5. What resources do I need to accomplish each action/effect?
The Engineer then constructed the Decision Support Overlay Matrix (DSOM) on paper, taking the NAIs, TAIs and DPs from the paper map and linking them to each other, their location and purpose, and the asset that would be used to achieve the effect. There is a clear link between the NAIs, TAIs and on the hand-written flipchart, as shown in Appendix 7. The manual production of the DSOM on the paper flipchart offers a process of checking the logic of the DSO, making sure that the NAIs, TAIs and DPs link together and that the assets are being deployed to best effect (i.e., relating each asset to a purpose as the columns are next to each other in the flipchart version of the DSOM).

Q6. When and where do the actions take place in relation to each other?
The CoS led the discussion of how the force elements would move together through the battle (through a mixture of forward recce (reconnaissance), mounted and dismounted troops, and armoured vehicles) with logistical support and coordinated indirect fire ahead of them (controlled by the fire control lines – see Q7). This was enacted on the map from the start position to the end position to capture the synchronisation issues as shown in Appendix 8, which were recorded onto the Coordination Measures whiteboard as shown in Appendix 9. The coordination measures were used as a precursor to the construction of the synchronisation matrix.

Q7. What control measures do I need to impose?
The fire control measures were developed by the Battle Group Commander, to ensure that the indirect fire ordinance would not be placed on the advancing force elements, or beyond the boundaries of the Battle Group's area. Five fire control lines were drawn onto an overlay on the paper map and numbered one to five. Each line was given a name, which was entered into the staff officer's notebook against the number used on the overlay as shown in Appendix 10. The convention of naming phase lines was to ensure coordination between the force elements and indirect fire during the operational phase. These activities form the battle plan for the Battle Group. This plan is turned into orders for each of the Companies the Battle Group is directing. Any minor changes to the plan, such as a delay in the timings or a reallocation of a unit (which might become apparent from the updated CCIRs), will mean that a Fragmented Order (FRAGO) is issued to the relevant Company.

Analysis of observed vignette and comparison of media used

The record of the media used in this vignette is presented in Table 1, which indicates a variety of media including paper, maps, overlays, whiteboards, flipcharts and staff notebooks (i.e., the shaded cells in Table 1). Observation of the planning process suggests that the Combat Estimate method, media and products work well together. The plan was constructed within the two hour time frame, with only 17 minutes per question, and the staff officers had no difficulty using the conventional media. No difficulties were noted working between media, such as taking the effects schematic (Q3) from the flipchart and COA (Q4) from the flip chart to produce the DSO (Q5) on an overlay. Similarly there were no problems noted for taking the DSO (Q5) from the overlay to produce the DSOM (Q6) on a flipchart. The point here is that translation between the media was straight-forward, as all media and products were available for the staff officers to use at all times. The planning media and methods were not seen as a constraint on the planning process.

Table 1 - Media used during the planning process

Media / Products	**Paper**	**Maps / Overlays**	**White-board**	**Flipchart**	**Staff Notebook**
Warning Order	■				
Planning time line			■		
Q1. BAE/TI		■			
Q2. Mission Analysis			■		
Q2. CCIRs/RFI			■		
Q3. Effects Schematic				■	
Q4. COA				■	
Q4. DSO		■			
Q5. DSOM				■	
Q6. Wargame		■			
Q6. Co-ordination			■		
Q7. Fire control		■			■

The optimal choice of type and mode of communication within and between the cells in a HQ is likely to be heavily dependent on the activity conducted. For some activities a textual document or a graphical image is more appropriate than a spoken alternative or vice-versa. The stage of any activity is also likely to heavily influence the optimal communication approach. Table 2 shows the degree of collaboration and cooperation required for different stages of the planning process. There is a clear

divide; the latter stages of the process (Q4-Q7) are best supported by collaboration (actors working individually with shared information). The earlier stages are much better suited to cooperative activity where the actors work together on one single product. Walker, et al. (2009) report on the basic human communication structures seen inside a BG HQ, identifying eight key functions, some of which are comprised of further sub-functions. The eight key functions include the Higher Command Formation, the Battle Group Commander (CO), Chief of Staff (COS/2IC), the 'Principal' Planning Staff such as the IO/G2 (to varying extents it also requires the participation of individual roles such as Recce/ISTAR, Eng, A2/Log and Arty/AD. There are also other ancillary command staff (such as those responsible for more general tasks and information management), which are called sub-units in the HQ (who are typically carrying out activities live in the battlespace) and, finally, the collection of graphics and planning aids derived from the Combat Estimate (artefacts that represent and transform information in some manner).

Walker, et al. (2009) describe the human network as dynamic with different functional nodes and links becoming active under different activity stereotypes. The activity stereotypes that they identified were: providing direction (i.e., the Battle Group Commander directing communications and information outwards to subordinate staff in a prescribed and tightly coupled manner); reviewing (i.e., the planning/principal staff communicate in a more collaborative manner with mutual exchange of information and ad-hoc usage of planning materials and outputs); and semi-autonomous working (i.e., the headquarters staff are working individually on assigned tasks and become relatively loosely coupled in terms of communication.

Table 2 – Team work required for each stage of the planning process

Digital MP/BM Estimate Question	**Task work or team work**
Q1. What is the enemy doing and why?	Cooperative activity around the table
Q2. What have I been told to do and why?	Isolated intellectual activity followed by collaborative activity around the table
Q3. What effects do I want to have on the enemy?	Isolated intellectual activity followed by cooperative activity around the table
Q4. Where can I best accomplish each action/effect?	Collaborative activity in which the products are shared
Q5. What resources do I need to accomplish each action/effect?	
Q6. Where and when do the actions take place in relation to each other?	
Q7. What control measures do I need to impose?	

The communication channels remain open but used in an ad-hoc, un-prescribed manner). These basic structures account for most of the formal communications. The human network structure is complex, but some of the links are identified in Figure 2.

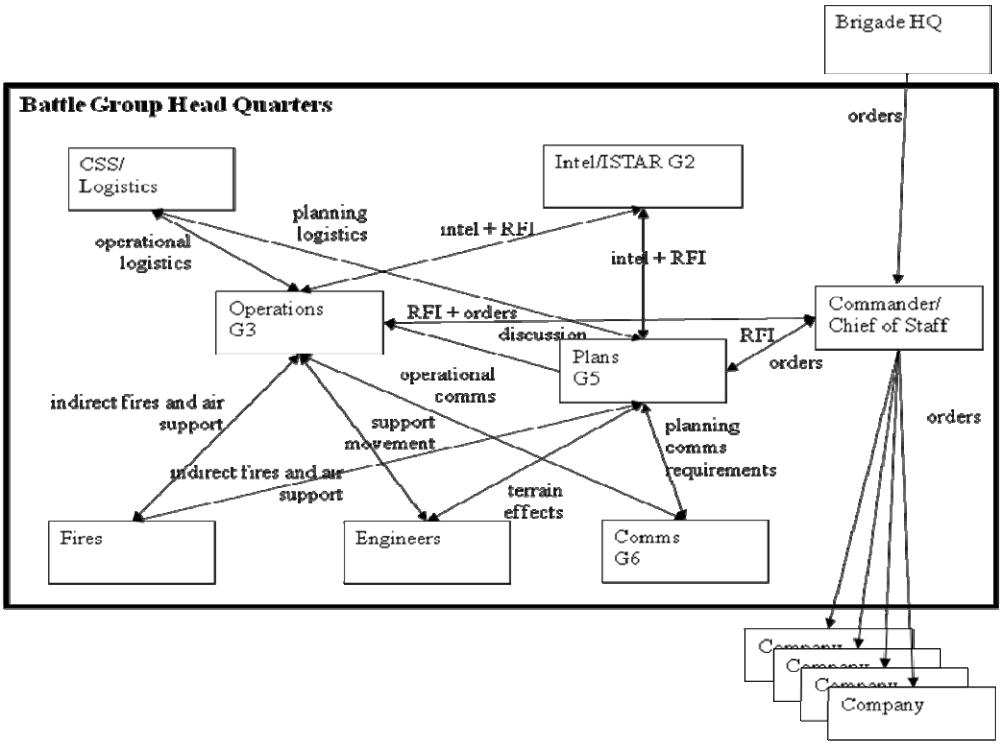


Figure 2. Relationships between the cells in Battle Group Head Quarters during mission planning

As Table 2 and Figure 2 indicate, the process of mission planning is a collaborative (i.e., working together on planning products) and co-operative (i.e., working in parallel on planning products) process, both in terms of the contribution to the products and the verbal interactions. It is also very obvious that the planning team surrounds themselves with the planning artefacts. Maps, overlays, white-boards, and flip-charts adorn every surface. The plan is constructed in the physical space between these artefacts, as information is collected, transformed and integrated from the cognitive artefacts and the interactions between the members the planning team. The training that planners undergo reinforces the fact that the information needs to be 'public', for all to see and interact with. The planning process appears to focus on identifying the constraints (such as the mission, the enemy, the environment, the resources and assets) to help define the possible courses of action. The process also requires an understanding of enemy doctrine and tactics to anticipate their likely behaviour and responses as well as military experience to know what effects are likely to achieve the desired outcome. Although it is difficult to quantify, there is certainly the opportunity for creativity in the way in which the plan is constructed. The planning team are continually trying to identify ways in which they can get the most from their finite resources and assets as well as preventing the enemy from anticipating their strategy. The planning process is also required to be flexible, as the it is continuous – as the process of issuing FRAGOs suggests. Whilst there hasn't been the space to discuss the interaction between planning and operations, these two cells are tightly coupled, as operations ensure planning and re-planning is being undertaken in light of the operational demands and constraints.

Implications for digitisation

Moves have been made to develop digital systems to support the planning processes (see Riley, et al., 2006 and Roth, et al., 2006 for just two examples). The focus of these activities has been on the products of the planning process for distribution between the planning team and to other people in the network within the HQ. The challenge to system designers has been to preserve the collaborative, public and creative parts of the planning process as well as supporting different levels of plan fidelity (which will depend on the time available to develop the plan). Perhaps the biggest challenge is to decide what needs to be digitised and what form this digitisation should take. Given that military planning teams have invested considerable effort in developing and refining their planning skills using the traditional media, it would seem appropriate to try and support these activities rather than requiring them to develop a new set of skills. The planning process has evolved over centuries of refinement and improvement (Clausewitz, 1832). Roth, et al., argues that much insight may be gleaned from studying the work-arounds and home-grown cognitive artefacts that are being used by command and control teams (such as the so-called 'cheat-sheets' and sticky notes). The traditional analogue planning process (as described earlier) is certainly abundant with potential metaphors, such as overlays, stickies, routes, COAs and so on. It is worth considering if the conventional media could be captured digitally (by camera, scanner, or other means) if they need to be transmitted as electronic documents with orders or reports, or for wider distribution. As a general design principle, the production of electronic documents should be at least as easy as the production of their analogue equivalents. Baxter (2005) is wary of the inexorable trend to digitise and concerned by the history of technology failing to deliver expected benefits, this is not just linked to military experience (Stanton and Marsden, 1996; Sinclair, 2007). Baxter argues that very few people understand the interrelated issues for technology, operations and human factors (being conversant in just one of these topics is not sufficient). Transformational approaches are likely to cause more problems than they solve. There are concerns that digitisation will lead to additional 'emergent' work (Kuper & Giurelli, 2007), both in terms of increasing the amount of 'direct' work required as well as the work associated with operation of the digital tools. The emergent nature of the task-artefact cycle has been described by Carroll (2000). Certainly it will not be possible to predict all the ways in which any future system would be used, so it is important to make the system as flexible as possible so that users may adapt it to suit their purposes (Roth, et al., 2006). Kiewiet, et al., (2005) noticed that there are marked differences in the planners' domain knowledge, pointing out that group planning ensures an integrated approach rather than an overemphasis on one planner's area of strength. The social aspect of planning has not been lost on other researchers (Houghton, et al., 2006; Stanton, et al., 2006; Walker, et al., 2006; Jenkins, et al., 2008). The collaborative aspects of planning seem to be a key to successful mission planning. As in the observational case study reported in this paper, Riley, et al., (2006) identified different cells contributed to the planning process, such as intelligence, operations, logistics, fire support, engineering and air defence. Kuper & Giurelli (2007) argue that design of collaborative tools to support command and control teams is one of the keys to effective team work. The case study presented by Riley, et al., (2006) shows how Human Factors can contribute to the design of a mission planning system which is based on a thorough understanding of the planning process, the demands and constraints. In design of their prototype tools they stress the need to provide a quick visualisation of the plan and the current situation. This enables the current operational picture to be compared with the plans, which may

require changes to the plan as the situation changes (Stanton et al, 2008, a; Stanton, et al., 2008, b).

References

Baxter, R. (2005) Ned Ludd encounters Network Enabled Capability. RUSI Defence Systems, (Spring 2005), 34-36.

CAST (2007) The Combat Estimate. Land Warfare Centre: Warminster. (Unpublished MoD document)

Carroll, J. M. (2000) Making Use: Scenario-Based Design of Human-Computer Interactions. MIT Press: Mass.

Clausewitz, C. Von (1832) On War (found at: http://www.clausewitz.com/CWZHOME/VomKriege2/ONWARTOC2.HTML accessed on: 15 August 2007)

Houghton, R. J., Baber, C., Mcmaster, R., Stanton , N. A., Salmon, P., Stewart, R. & Walker, G. (2006) Command and control in emergency services operations: A social network analysis. Ergonomics 49 (12-13), 1204-1225.

Jenkins, D. P., Stanton, N. A., Walker, G. H., Salmon, P. M. & Young, M. S. (2008). Using Cognitive Work Analysis to explore activity allocation within military domains, Ergonomics, 51 (6), 798-815.

Kiewiet, D. J., Jorna, R. J. And Wezel, W. V. (2005) Planners and their cognitive maps: an analysis of domain representation using multi-dimensional scaling. Applied Ergonomics, 36, 695-708.

Klein, G. and Miller, T. E. (1999) Distributed planning teams. International Journal of Cognitive Ergonomics, 3 (3), 203-222.

Kuper, S. R. and Giurelli, B. L. (2007) Custom work aids for distributed command and control teams: a key to enabling highly effective teams. The International C2 Journal, 1 (2), 25-42.

Levchuk, G. M., Levchuk, Y. N., Luo, J., Pattipati, K. R. and Kleinman, D. L. (2002) Normative design of organisations – Part I: Mission Planning. IEEE Transactions on Systems, Man and Cybernetics – Part A: Systems and Humans, 32 (3), 346-359.

Moltke, H. K. B. G. von (undated) http://en.wikipedia.org/wiki/Helmuth_von_Moltke_the_Elder (accessed on 15 August 2007)

Prefontaine, R. (2002) The administrative estimate in the operation planning process: a toll not well understood. The Army Doctrine and Training System, 5 (4), 4-12.

Riley, J. M., Endsley, M. R., Bolstad, C. A. and Cuevas, H. M. (2006) Collaborative planning and situation awareness in Army command and control. Ergonomics, 49 (12-13), 1139-1153.

Roth et al (2006) Evolvable work-centred support systems for command and control. Ergonomics, 49 (7), 688-705.

Sinclair, M. A. (2007) Ergonomics issues in future systems. Ergonomics, 50 (12), 1957-1986.

Stanton, N. A. & Marsden, P. (1996) From fly-by-wire to drive-by-wire: safety implications of automation in vehicles. Safety Science, 24, (1) 35-49.

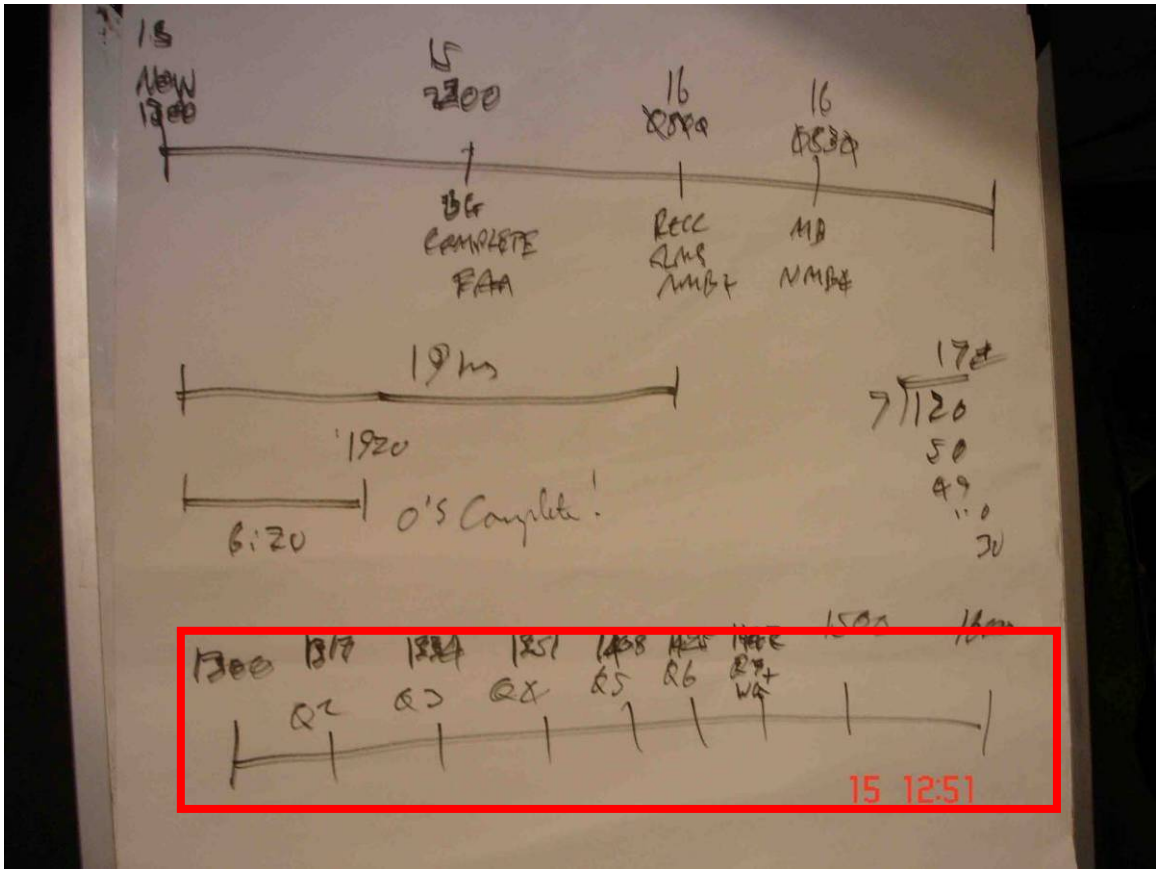
Stanton, N. A., Baber, C. & Harris, D. (2008, a) Modelling Command and Control: Event Analysis of Systemic Teamwork. Ashgate: Aldershot.

Stanton, N.A., Baber, C., Walker, G.H., Houghton, R.J., McMaster, R., Stewart, R., Harris, D., Jenkins, D.P., Young, M.S., Salmon, P.M. (2008, b) Development of a generic activities model of command and control, Cognition, Technology and Work, 10, (3) 209-220.

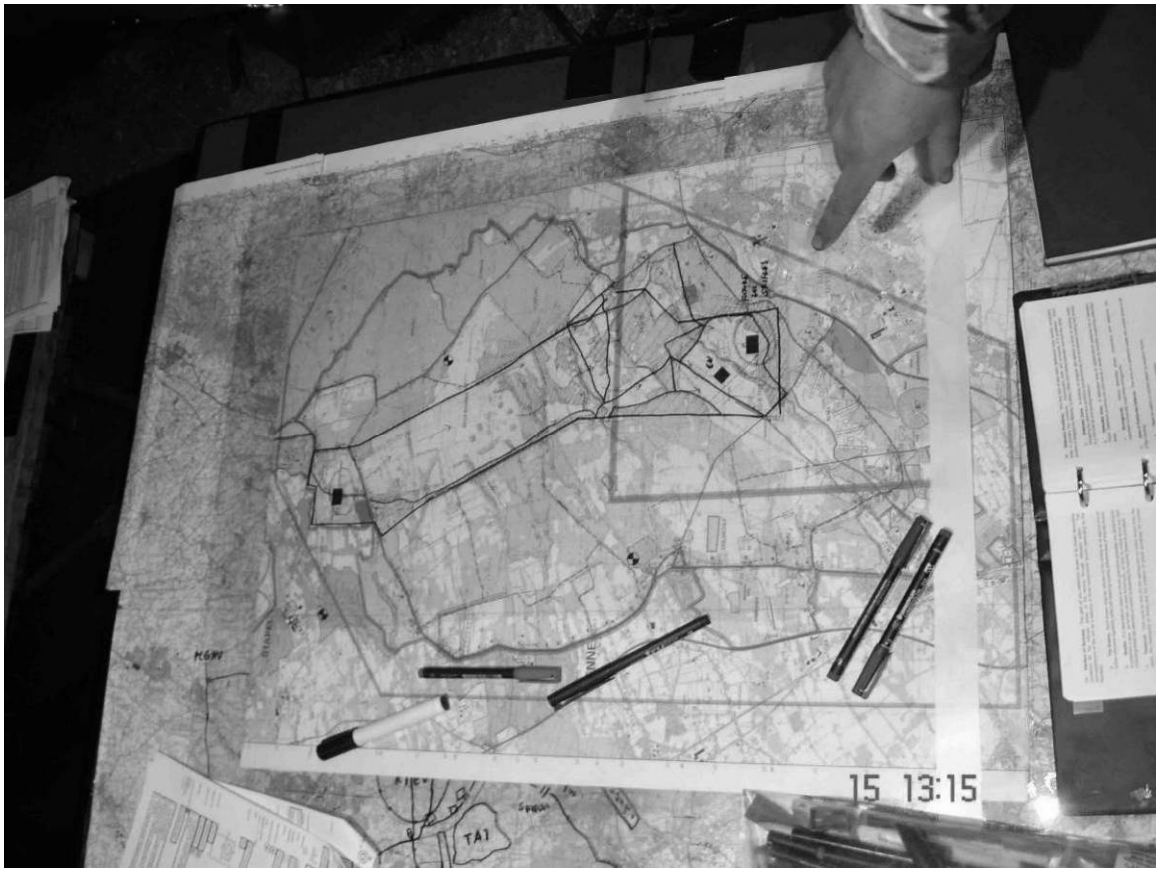
Stanton, N.A., Stewart, R., Harris, D., Houghton, R.J., Baber, C., McMaster, R., Salmon, P., Hoyle. G., Walker, G., Young. M.S., Linsell, M., Dymott, R. and Green, D. (2006). Distributed situation awareness in dynamic systems: theoretical development and application of an ergonomics methodology. Ergonomics 49 (12-13), 1288-1311

Walker, G.H., Gibson, H., Stanton , N.A., Baber, C., Salmon, P. and Green, D. (2006) Event Analysis of Systemic Teamwork (EAST): A novel integration of ergonomics methods to analyse C4i activity., Ergonomics 49 (12-13), 1345-1369.

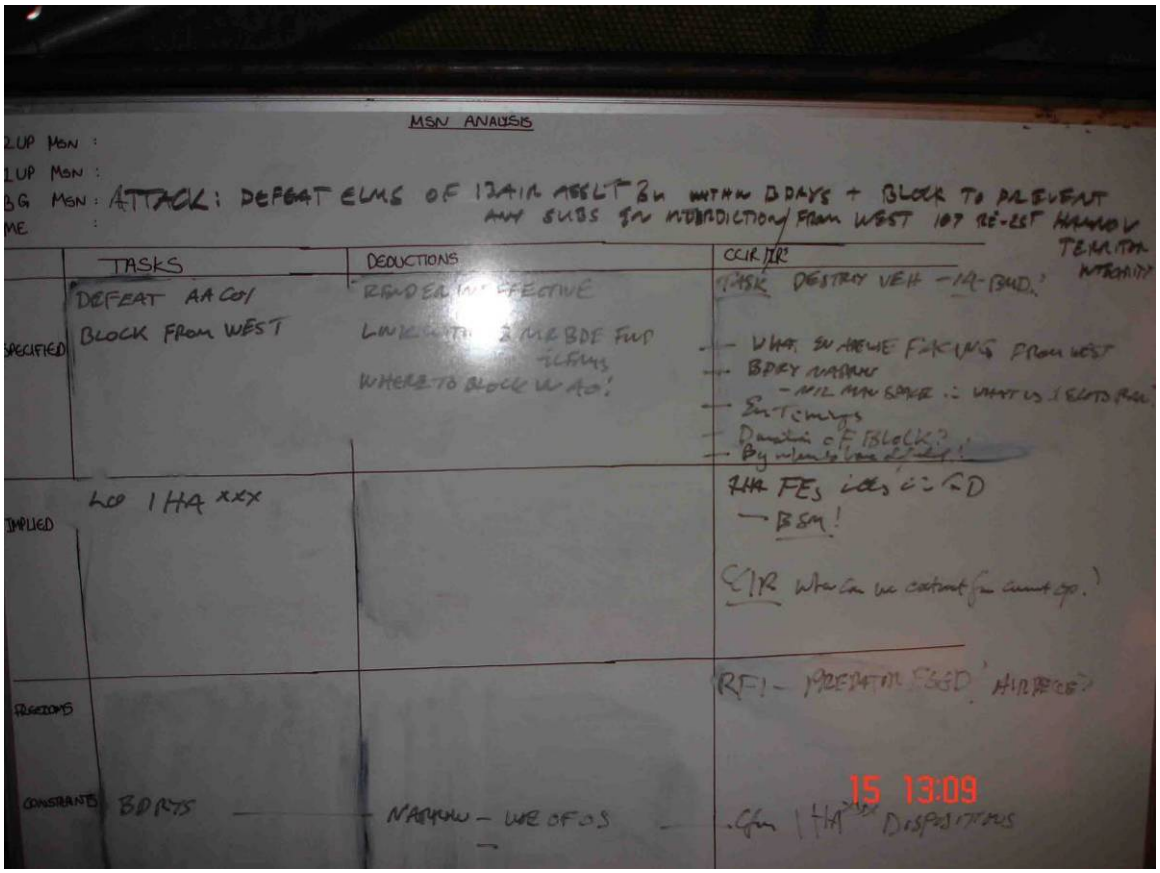
Walker, G. H., Stanton, N. A., Salmon, P., Jenkins, D., Stewart, R. & Wells, L. (2009) Using an integrated methods approach to analyse the emergent properties of military command and control. Applied Ergonomics (in press)



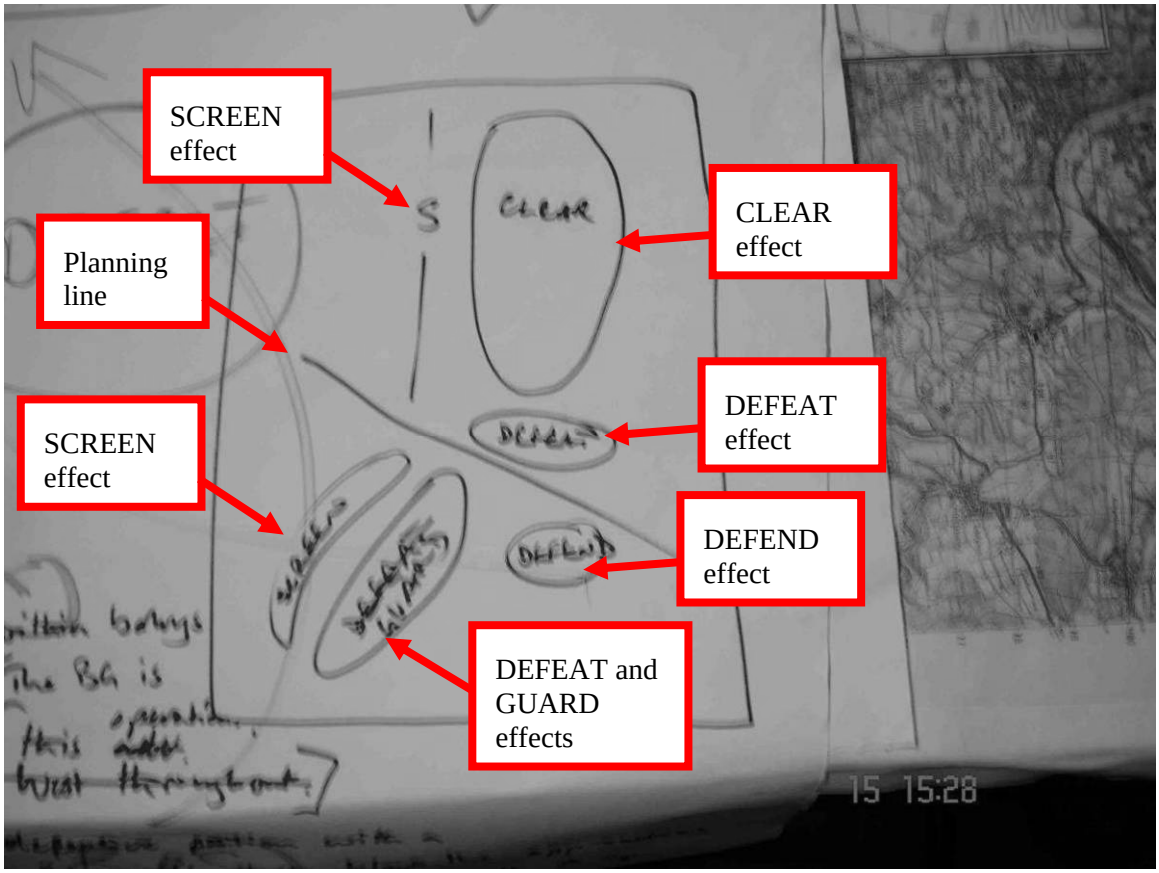
Appendix 1 - Planning timeline on a flipchart



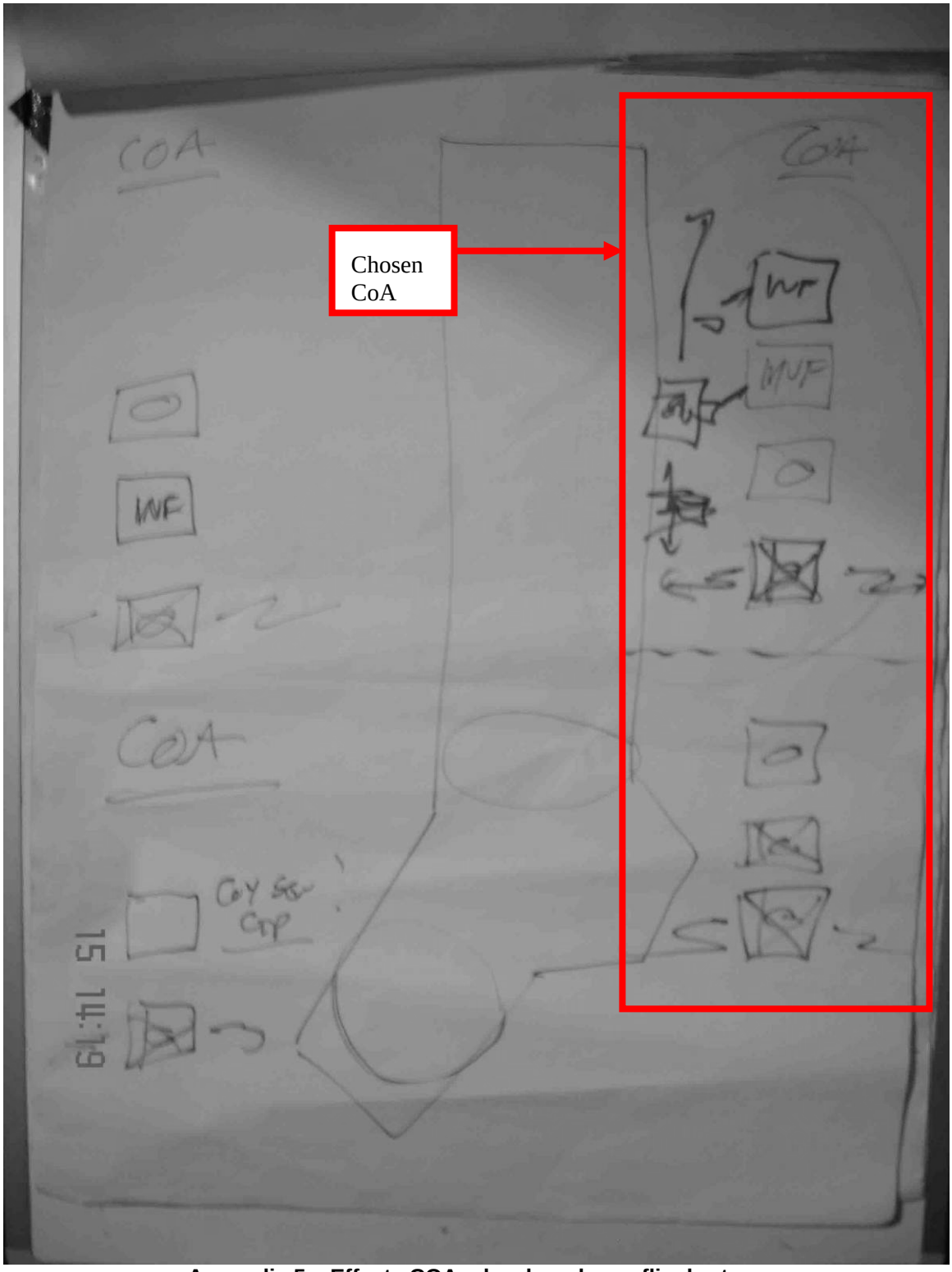
Appendix 2 - Threat integration on map and overlay



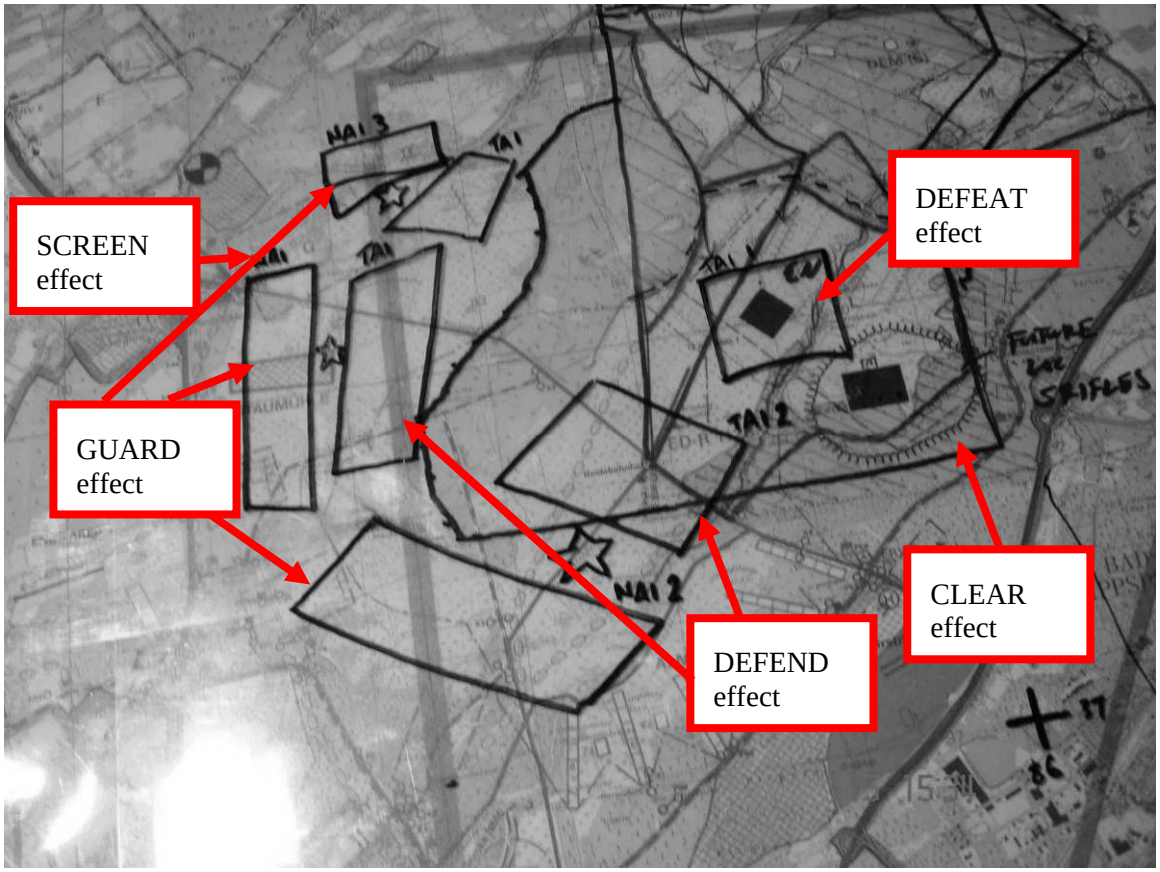
Appendix 3 - Mission Analysis on a whiteboard



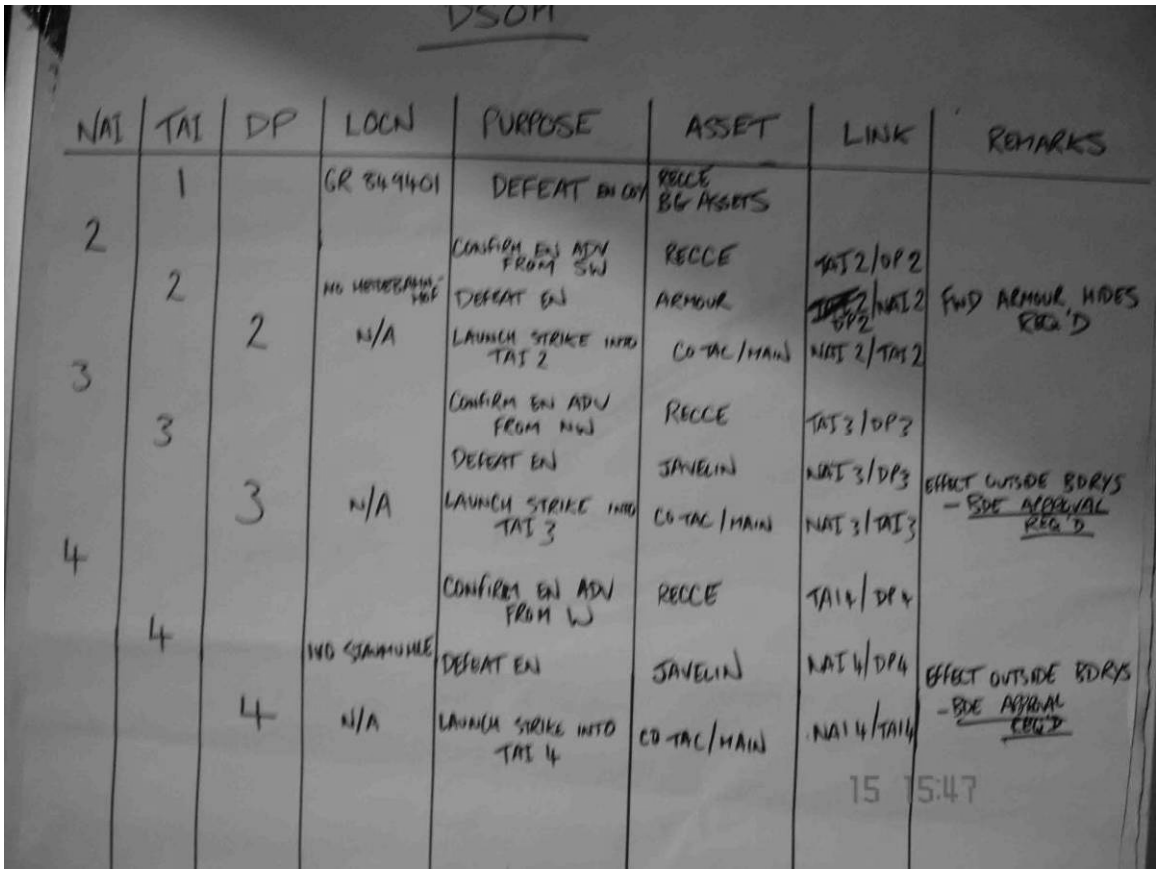
Appendix 4 - Effects Schematic drawn on a flipchart and laid on the map



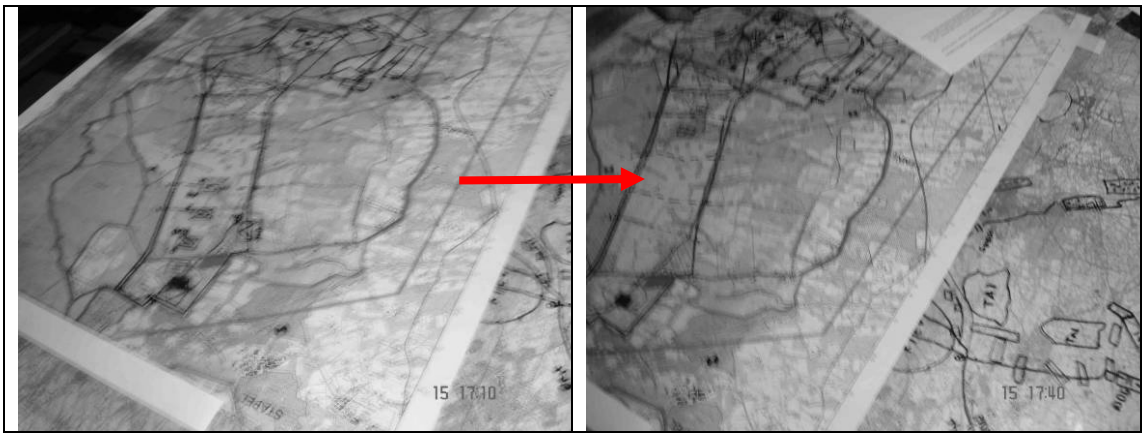
Appendix 5 – Effects COAs developed on a flipchart



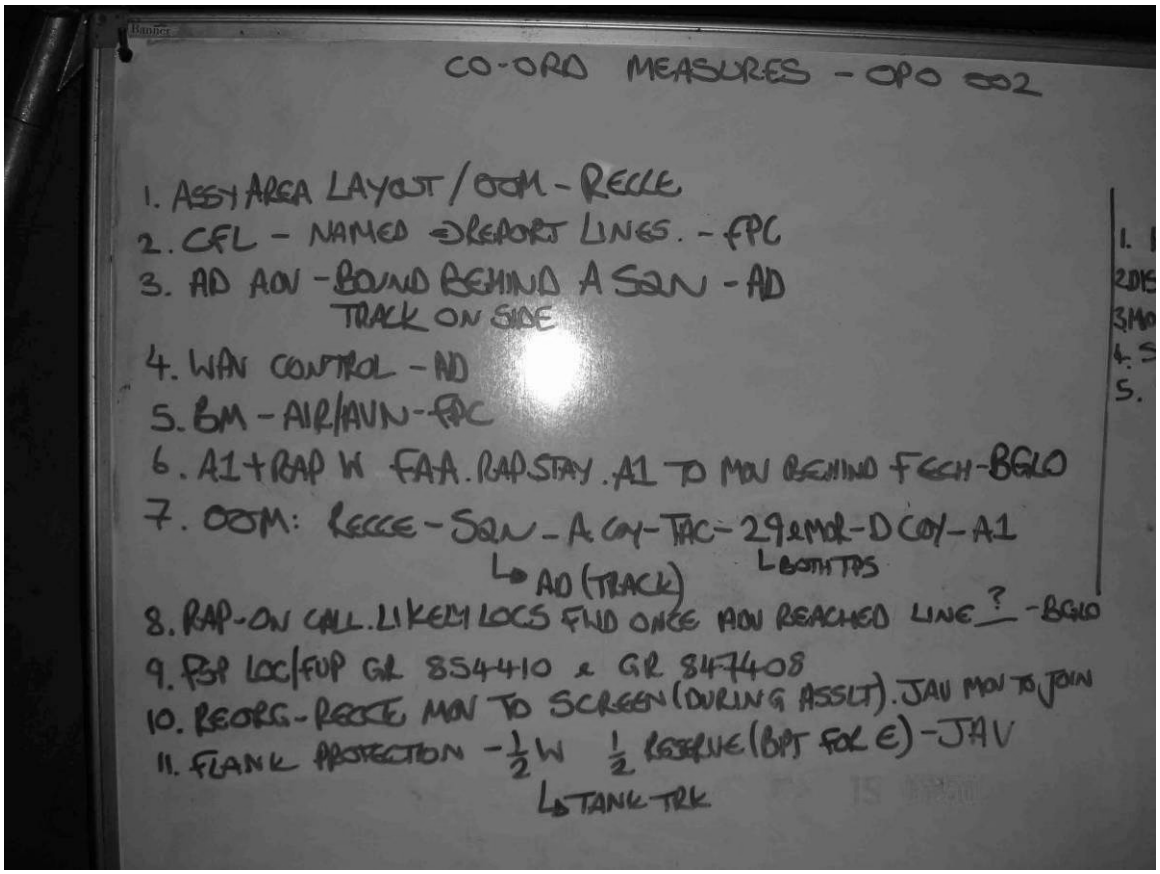
Appendix 6 - DSO on map and overlay



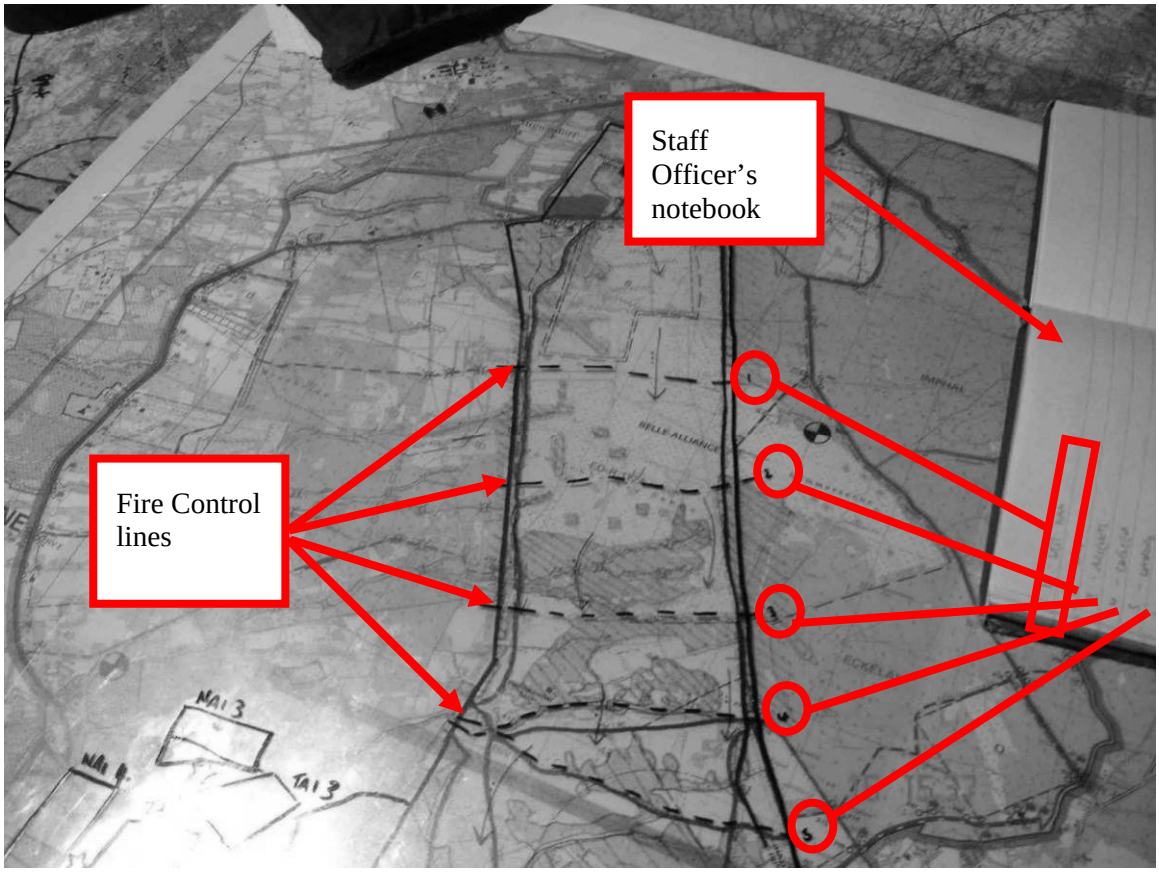
Appendix 7 - DSOM on a flipchart



Appendix 8 - Coordination of force elements on map and overlay via a wargame



Appendix 9 - Coordination Measures captured on a whiteboard



Appendix 10 - Fire control lines on map and overlay also recorded in staff officer's notebook